Breast Cancer Treatment by Combining Microwave Hyperthermia and Radiation Brachytherapy

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Abstract –

Combination of microwave hyperthermia and radiation brachytherapy is effective for treatment of tumor. After increasing the temperature the tumor becomes more sensitive to radiation dose. In this paper, the Invasive antenna array was designed and applied on different tissues including malignant tumor, and respective Specific Absorption Rate (SAR) patterns and temperature rises were investigated. The objective in the current phase of research work is to find the most optimum antenna array which can be effectively used for breast tumor with minimal impact on the adjacent tissues. Both theory and experiment demonstrated that the maximum SAR occurred in the junction plane of antenna arrays. These experiments have been conducted using 2.45GHz.

***Index Terms* — Antenna array, microwave hyperthermia, radiation dose, Specific Absorption Rate**

1. Introduction

Microwave-hyperthermia is a method of treating cancer by heating the tumor. Once a tumor is heated, either it dies or becomes more sensitive to radiation brachytherapy using radioisotopes. Thus, with an appropriate rise in temperature by hyperthermia, the conventional radiation dose can be minimized [1], and a combination of these two methods can be more effective in reduction of tumor [2]. By use of an appropriate antenna array, temperature rise to about 42˚C-45˚C is achieved. The primary motivation of this paper is to evaluate the characteristics of coaxial-slot antenna applied on breast tumor and effectiveness of combination of hyperthermia and radiation dose on the tumor. It is important to evaluate the application of antennas on breast tumor as the tumor has particular relative permittivity and conductivity. A coaxial-slot antenna increases the temperature locally and after applying hyperthermia, application of radiation dose increases the effectiveness in reducing the tumor.

2. Description of the Antenna array system

Antenna geometry parameters and the spacing between the slots for invasive antennas were calculated for the frequency 2.45 GHz and were designed particularly for breast tumor [3]. The coaxial-slot antenna was designed and applied on breast tumor phantom as shown in Figure 1.

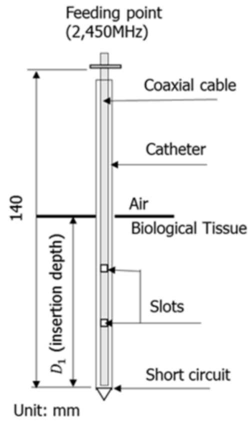

Figure. 1 Coaxial-slot antenna with two slots

For better result, two coaxial-slot antennas were used. These antennas were separated by 0.5cm.

3. Calculation of SAR and temperature

The basic concept for determining SAR relies on the fact that a tissue or the phantom material exposed to electromagnetic radio waves absorbs power from the electro-magnetic waves and this power gets distributed throughout the tissue or phantom material. It is defined by Equation (1).

$$|SAR| = \sigma . \frac{|E|^2}{\rho} \qquad \text{Equation (1)}$$

Where σ is the conductivity of the tissue (S/m), ρ is the density of the tissue (kg/m^3), and |E| is the electric field (V/m). The electromagnetic field around the antenna was calculated by use of FDTD. SAR of the tumor tissue phantom is shown in Figure 2. The basic concept for determining SAR relies on the fact that if the tissue or the phantom material is at a thermal equilibrium, then immediately after power is applied to the phantom, the initial power absorption is related to SAR.

Temperature rise inside the tumor due to application of coaxial-slot antenna array was also calculated. This temperature rise is shown in Figure 3. Penne's bio-heat transfer equation, shown in Equation (2), was used to calculate the temperature. Body temperature was considered to be 27˚C.

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$$(\rho.c_p)_t \frac{\partial T_t}{\partial t} = \nabla.(k_t.\nabla T_t) + q_p + q_m \quad \text{Equation (2)}$$

Where ρ, c_p, T_t, k_t, q_p, q_m are tissue density, tissue-specific heat, tissue temperature, tissue thermal conductivity, heat transfer from blood to tissue, and uniform rate of metabolic heat generation in the tissue layer per unit volume, respectively. Thermal conductivity of the tissue and that of the material which was used to fabricate the antenna was calculated using Maxwell's equations and shown in Equation (3).

$$\frac{J_c}{\sigma_s} = \frac{D}{\epsilon} \quad \text{Equation (3)}$$

Where J_c, σ_s, D, ε are electric current density, thermal conductivity, electric flux density and permittivity of the material.
Radiation dose distribution in breast tumor was calculated and appropriate rise in temperature was considered to be within the range of 42˚C-45˚C. Purpose was to understand how much radiation dose distribution can be reduced as compared the conventional dose and also can be effective for breast tumor.

4. Results

The power distribution from two coaxial-slot (invasive) antennas on the tumor phantoms was observed in CST simulation and experiment were conducted. The pattern is developed around the slots. In this particular coaxial-slot antenna, two slots were made to achieve efficient heating. Figure 2 shows the SAR distribution from two coaxial slot antennas in tumor. SAR of other tissues such as fibro glandular tissue, muscle were also calculated. In this research, as breast tumor is the region of interest for the authors and as the calculations are focused on it. The SAR was found maximum for tumor. Further, the SAR was found to be maximum at the junction of the two coaxial-slot antennas.

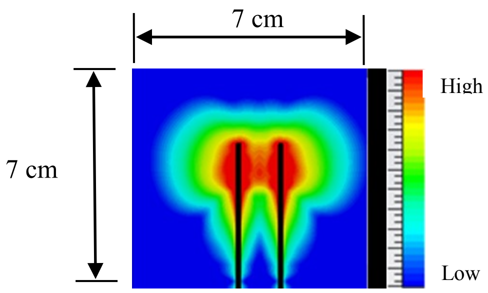

Figure2. SAR distribution of the coaxial-slot antenna array in tumor phantom

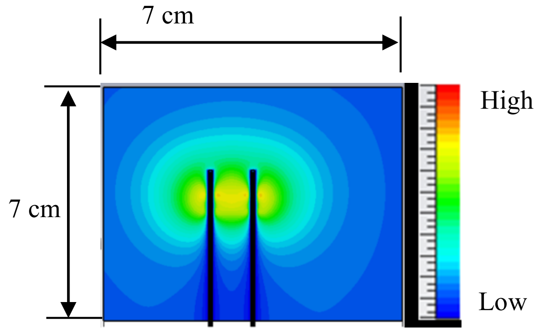

Figure.3 Temperature increase after application of coaxial-slot antenna array in tumor phantom

Breast Tissue is made up of different tissues, due to which it is difficult to heat only the tumor keeping the adjacent tissues intact. The author has focused on invasive antenna to minimize the impact on adjacent tissues. After application of the antenna array, the co axial-slot antenna would be removed whereas the catheter remains in the same place. In the catheter, the radiation source would be introduced as shown in figure 4. In this case, Iridium-192 radiation source would be applicable for breast tumor.

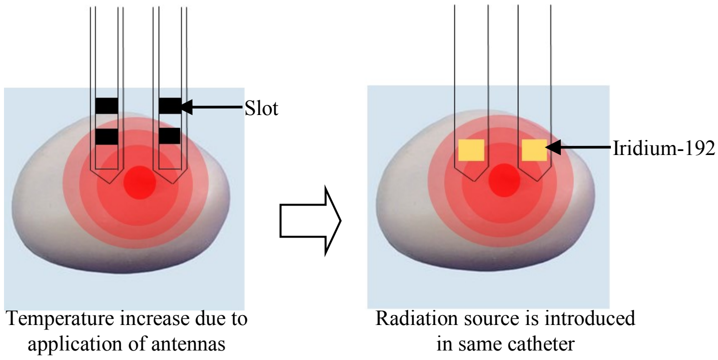

Figure.4 Combination of two methods: hyperthermia and radiation dose distribution for breast tumor

5. Conclusion

Hyperthermia increases the temperature of the tissues to around 42˚C-45˚C. Antenna array is used in such a way that the temperature increase take place in the localized area and does not affect the adjacent tissues. For invasive antenna, after 10 minutes of heating, around 8˚C temperature rise was observed. Though the time taken is more, no adjacent tissues are heated. Thus after application of such antenna array, a low dose of radiation can be effective for treatment of breast tumor.
Future work will focus on optimizing the radiation dose distribution in the tumor and on finding how much reduction is possible for radiation dose.

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